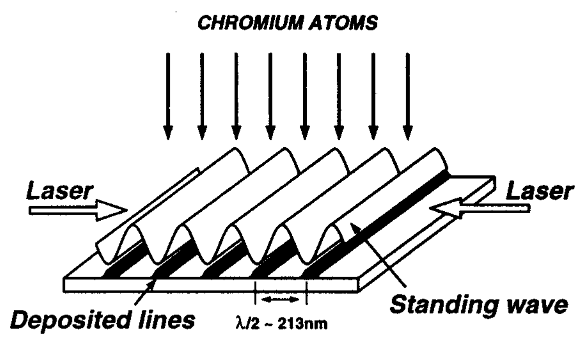
Laser Focusing of Chromium Atoms for Nanostructure Fabrication

J. J. McClelland, R. Gupta, and R. J. Celotta
Electron Physics Group, MET B206
National Institute of Standards and Technology, Gaithersburg, MD 20899
Phone: (301) 975-3721 Fax: (301) 926-2746 email: jabez@epg.nist.gov

Fabrication of nanostructures, i.e., structures with dimensions less than ~100 nm, is of great interest both from a technological and a fundamental point of view. Technological applications include microelectronic devices with smaller feature size, magnetic storage media with higher bit density, and novel material fabrication. Fundamental interests include, for example, quantum wells, nanostructured materials, and few-atom systems.

We have demonstrated a new form of nanostructure fabrication that has many potential advantages over existing techniques such as optical lithography or electron beam lithography. While optical lithography reaches its diffraction limit at around 180 nm, our new technique has demonstrated line widths as small as 38 nm and is predicted to have an ultimate resolution near 10 nm. Electron beam lithography can make features this small, but must do so serially rather than in parallel, as can be done with laser focusing of atoms.



Focusing of atoms in a standing-wave laser field creates nanostructures on a surface.

Our process involves depositing chromium atoms onto a surface while passing them through a laser standing wave[1,2] (see figure). The laser light is tuned near, but 500 MHz above, the resonance line at 425.55 nm (vacuum wavelength). In the presence of the laser field, the atom acquires an oscillating dipole moment, which causes it to feel a force toward the nodes of the standing wave. The force can be modeled as arising from a nearly quadratic conservative potential, so true first-order focusing of the atoms is achieved.

Both one-dimensional and two-dimensional[3] arrays of nanostructures have been fabricated with this technique. The structures are air-stable, and are typically imaged by atomic force microscopy. Currently, work is underway to investigate a wide range of extensions and applications of this process. Extensions include replication of the patterns with polymer molds, improvement of the atom source characteristics to allow attainment of the theoretical resolution limit, and scanning of the substrate to generate arbitrary patterns. Applications include the study of atom distributions in a laser field, generation of a nanometer-scale length standard, and fabrication of magnetic nanostructures. This work is supported in part by NSF grant PHY-9312572.

References

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